SNAP Error Budget

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1 Introduction

This note discusses a strategy in the treatment of known systematic errors to the cosmology fit. We will go through the identified sources of errors that appear in the SNAP proposal, plus a few others, and will try to explain how one would deal with them: whether they are SN Ia dependent or z-bin dependent, whether they correlate with redshift bin, which, whether and how errors can be constrained from other measurements, etc. For each source of error, we provide:

1. A short explanation of its origin.
2. The value for the SCP analysis.
3. The expected value for SNAP.
4. The treatment that we propose, including an assessment of correlations.
5. The person in charge of providing the detailed information on the actual number.

2 Extinction and Reddening

2.1 Milky Way Extinction

1. Absorption of light in our galaxy due to dust and gas in the interstellar medium of the Milky Way. In general shorter (blue) wavelengths are absorbed or scattered preferentially out of the line of sight compared to longer wavelengths.
2. Current value of the contribution to the peak magnitude is < 0.04 mags. but could actually be larger, almost 0.10 mags depending on line of sight and wavelength.

3. 0.01 per supernova at peak magnitude. We assume that this error will be much reduced because of new measurements of galactic extinction that will be made by SIRTF, SDSS and SNAP itself. For example by taking spectra of about 100 hot subdwarfs in the SNAP fields.

4. Decreases with z as restframe blue is redshifted. Independent along different lines of sight. We assume all SN are in different LOS). About 0.01 (guess) per SN. Negligible for a 70 SN bin.

5. cf. Schlegel, Finkbeiner, Davis 1998 ApJ,500,525, Finkbeiner, Schlegel, Davis 1999 ApJ, 524,867 and Burstein and Heiles (1984 ApJS,54,33; 1982 AJ,87,1165; 1978 ApJ,225,40)

2.2 Extinction by Ordinary Dust Not in the MW

1. Absorption by dust in the host galaxy, which may (or not) have similar composition and properties of MW dust.

2. 0.03

3. < 0.01 per SN. Eliminated by cross-wavelength (spectra and/or photometry) calibration.

4. Spectra and multi-filter observations.

5. Ariel Goobar

2.3 Gray Dust

1. Absorption by intergalactic dust that does not absorb more blue than red, it presumably radiates in the infrared, and also affects distant objects more than nearby ones (secular effect) depending on how this dust is distributed... i.e. only beyond $z = 0.5$ and so forth.

2. Negligible at low redshift – no evidence for gray dust

3. Obtain SNe at both low and high redshift since the effects of gray dust will be different for SNe at different redshifts. Additional limits on gray dust will come from SCUBA/SIRTF observations.

4. Model dust effect with free parameter(s). Fit for additional parameter(s) constrained by SCUBA/SIRTF measurements. Should correlate for SNe in the same line of sight. Effect grows with z and is one sided (it is a bias)

5. Ariel Goobar

3 Host Galaxy Subtraction

1. Light from the galaxy underlying a SN is subtracted out – both in photometry and spectroscopy. Requires obtaining data a year or so after the SN has faded.

2. Error contributions have a range of values and depend on: position of SN in the host galaxy, redshift and wavelength range.

3. No good estimate yet at this time, but it should not be very large.

4. Subtraction errors are not correlated among different SNe.

5. Sebastien Fabbro.

4 Evolution – Diversity of SN Ia progenitor population

1. Effect of differences in mass, metallicity, orbital parameters, etc. of the SNe progenitors, which in principle translate into observable spectral and photometric features.

2. The effect is uncertain at low redshift, current estimates based on ground based spectra of low and high z (out to z=0.8) indicate a small effect, < 0.1 and probably already of order 0.05, however need large sample of SNe distributed in redshift, environment and so forth to determine effects on global scale.

3. Measure large number of parameters (rise time, spectral features, colors, etc.,) over a time series for many SNe.

4. Like-to-like comparison: perform different cosmology fits for subsamples of SNe with features pointing toward high/low metallicity, high/low progenitor mass, etc.

5. Peter Nugent

5 Malmquist Bias

1. The Malmquist Bias arises because in a magnitude limited (i.e. flux limited) sample, the volume element containing more distant, luminous objects is larger than that occupied by the nearer, fainter objects. In practice, for standard candles (objects which all have the same intrinsic luminosity)

like Type Ia Supernovae, this becomes for a given redshift range, essentially a bias towards brighter SNe.

2. contributes error of 0.04 magnitudes at the peak brightness.

3. is less than 0.02 mags (2%) at peak.

4. requires detection of every SN 3.8 magnitudes below peak (i.e. within 2 days after explosion or about 19 days in the restframe before peak brightness) What matters most is a possible difference in the bias between low and high z supernovae. One could change the magnitudes of low-z SNe by 0.02, for instance, and see what it does to the final result

5. Greg Aldering and Alex Kim.

6 Gravitational Lensing by Clumped Mass

1. This refers to lensing of SNe due to extragalactic mass between us and the SN. Lensing changes the apparent flux of a SN, with higher probability of being dimmed. Gravitational lensing has an asymmetrical distribution in the amplification of flux, with a longer tail in the direction of dimming the flux.

2. < 0.06 mags at peak brightness for each SN.

3. Current assumption is that this will become negligible (less than 1% at peak brightness) since there will be some 75 SNe per redshift bin (at different lines of sight) so the effect averages out with large number of SNe per z bin.

4. Models of lensing effects on supernova cosmology exist (cf. references below). Add asymmetric errors to covariance matrix. Gravitational lensing may correlate for SNe in the same line of sight, but need to check the correlation scale.

5. Bergstrom *et al* A&A 358, 13 (2000), Goliath *et al* astro-ph/0104009.

7 K-correction and Cross-Filter calibration

1. Type Ia Supernovae are brightest in the restframe B band (blue, centered at 4500 angstroms). The K-correction is applied to correct for the broadening and redshifting of the emitted light in a given restframe bandpass.

The amount of the effect depends on the source's redshift and on the observer's filter transmission and bandpass. The cross-filter calibration is needed to match the magnitude systems back to the restframe B band as different filters are used to observe low and high z SNe.

2. 0.025 mag. at peak brightness

3. less than 0.02 mags. with extensive cross-filter calibration and spectral time-series measurements.

4. To begin with, assume a residual systematic uncertainty on magnitude for each SN as function of redshfit of about 0.01, for instance, uncorrelated, and see the effect.

5. Kim et al., "A Generalized K Correction for Type IA Supernovae: Comparing R-band Photometry beyond z=0.2 with B, V, and R-band Nearby Photometry" (1996 PASP..108..190K). Calibration Working Group.

8 Non SN Ia Contamination

1. Up to 10% of ground-based samples of high z SNe can be contaminated by non SN Ia: AGNs, SN Ib or Ic can look similar to SNe Ia if spectra, specifically the Si II feature, is not observed.

2. $<$ 0.05 mag. at peak brightness

3. Eliminated, by measuring the Si II feature for all SNe, even at high z, where it lies in the near IR.

4. Might want to simulate the effect of very low signal-to-noise-ratio spectrum on confusion of line identification for redshifted SNe. Also should look at SN Ia "look-alike" spectra, e.g. other SNe, Hypernovae to check for confusion. Could one get known SNe Ib and Ic and include them in the sample to see the effect on the result? Effect of spectral resolution?

5.

9 Instrumental Errors

9.1 Detector Related Effects

1. Errors are introduced during image processing, the primary sources are bias subtraction and flatfielding, where a sky frame is divided into the

image frame. If dark frames are used, then the process of dark subtraction also will introduce noise in the final, reduced image. An additional source of noise comes from radiation events, commonly referred to as cosmic ray hits. The latter is a localized effect on the detector, each hit usually affects a small number of pixels. The total number of hits per frame depends on the cosmic ray rate, which in general is higher the further away a spacecraft is from the earth. Diffusion in the CCD.

2.

3. Errors due to bias subtraction and dark subtraction should be negligible, those due to flat fielding should be under 1%. Requires thorough understanding of detector behavior.

4. Errors are only pixel-dependent and, therefore, uncorrelated between different SNe.

5.

9.2 Point Spread Function

1. The point spread function (PSF) is the description of the resulting image shape of a point source (e.g. a star) due to the response of the entire optical system. An ideal system would have the same PSF everywhere in the field of view. In practice, however, the PSF changes with distance from the optical axis, with filter, and also with telescope orientation. PSF fitting allows for more accurate photometry as the object's light distribution is well mapped. Typical functions used are gaussians. However, these are not always adequate, especially for example in a crowded field like a star cluster, or where the object "sits" on top of another light distribution as in the case of a SN in a galaxy. Stetson , for example, uses a combination of analytical and empirical fits to the profile. Diffusion in CCD.

2.

3. Errors due to PSF Calibration should be less than 3% (statistical error), and about 2% (systematic error).

4. One would want to develop or adapt algorithms to fit the PSF for each frame, trading off computational speed vs. accuracy.

5. cf. Stetson 1987 PASP,99, 191 and later papers on stellar photometry.

9.3 Flux Calibration

1. Flux Calibration is the method by which the digital counts on the detector are converted to magnitudes, and/or physical units - ergs/cm^2/sec, in imaging or in spectroscopy. The procedure is to observe calibrated, standard stars with the same instrumental setup as the target objects. This provides the conversion factor to correct the received radiation.

2. 0.01-0.12 range for SNe.

3. The required precision of the flux calibration in the imager is less than 1% on the peak magnitude (statistical error) and of order 2% systematic error (ie. from the highest z SN to the lowest z SN)

4. Achieving this accuracy is demanding, and is exigent of a higher precision than has been available. More typical accuracy is of order 3-5 %. Fundamental requirement is establishing a system of extremely well calibrated standard stars, down to a magnitude of about 20 or so. In effect this demands a calibration program to be carried out specifically for the SNAP mission.

5. S. Deustua and the Calibration Working Group